Water Distribution 4

📖 Duration:
Pre-visit: 45 minutes
Visit: 15 minutes
Post-visit: 45 minutes

📖 Setting:
Classroom, Mission San José Grist Mill

📖 Skills: Grades 6-8
Math: 6.8 Solves application problems involving estimation and measurement of length, area, time, temperature, capacity, weight and angles.
7.9 Solves application problems involving estimation and measurement.
8.4 Makes connections among various representations of a numerical relationship.
Science: 6,7,8.1B Conducts field and laboratory investigations using safe, environmentally appropriate and ethical practices.
6,7,8.2 Uses scientific inquiry methods during field and laboratory investigations.
6,7,8.4 Knows how to use a variety of tools and methods to conduct science inquiry.
6.6C Identifies forces that shape features of Earth including movement of water.
7.8A Illustrates examples of potential and kinetic energy in everyday life such as movement of water.
8.7A Demonstrates how unbalanced forces cause changes in the speed or direction of an object's motion.

📖 Essential Terms:
water velocity, gravity, mechanical advantage, scale of map, flow chart

HUMAN PRESENCE

Big Idea
How did the early missionaries use existing technology to harness the energy of water?

Objectives

Students will:

- Measure the mill's water containment area to determine the pressure of the water that exits onto the turbine.
- Use a model to determine the effects of different depths of water on the rotation of turbine in the mill.
- Calculate the mechanical advantage (number of times force is multiplied) of the turbine.
- Demonstrate that water pressure on the bottom of a body of water increases with increased water depth.
- Prepare a written report using the data to form conclusions about the harnessing of energy from water.
- Present an oral report summarizing the data and conclusion of the investigations.
- Report data to San Antonio Missions National Historical Park.

Making Connections

The early Spanish missionaries used existing technology to harness the energy of water. A*cequias* were dug to transport water from the San Antonio River to *labores*, or fields (see Structure Big Idea). In 1794 a gristmill at Mission San José was constructed to grind wheat. They used the science concept that pressure in water in any one place is the same in all directions. To obtain more pressure, the most important measurement to increase is the depth of the water. The mission Indians constructed a well (water containment area) adjacent to the mill. The mill's turbine was

placed below the level of the containment area to take advantage of increased water pressure caused by the increased depth. Running the water down a chute to the turbine further increased water velocity. The water increased in pressure due to the force of gravity.

Materials

Engagement/Explanation (pre-visit):

- science text
- scale drawings of mill
- plumb bob on a string tied to a stick

Exploration (visit):

- scale drawings of mill
- plumb bob on string tied to a stick
- string

Elaboration (post-visit):

- 2 3-liter bottles
- scissors
- meter stick
- 2 corks
- pin wheel

Extension (post-visit):

- 2 meters of 2" PVC pipe with same sized holes drilled in a vertical line every 20 cm
- 2 meters of 4" PVC pipe with one hole (same size and same distance from the bottom as the 2" pipe)
- PVC caps for both pipes
- corks for holes
- pin wheel
- graduated cylinder
- gallon jar of water

Engagement/ Explanation (Pre-visit):

How do you measure the pressure of water in the mill containment area?

1. Use the scale drawings of the mill and the formula below to calculate the water pressure in the containment area. Record the data. Formula to determine the pressure of water in the containment area:

Pressure of the water at the turbine =
Density of the water X
Depth of the containment area (including the chute that directs water to the turbine) X
Acceleration due to gravity

Density of water = $1000kg/m^3$
Acceleration due to gravity = $9.8m/s^2$

2. Use the scaled drawings of the mill to determine the number of square meters there are in the chute opening. Record the data.

How do you measure the force water exerts on the turbine?

3. Use the formula below to calculate the water force on the turbine. Record the data. Formula to determine the force on the turbine:

Force on the turbine = Water pressure at the turbine X Area of the chute

By what method does one determine the mechanical advantage of the water wheel?

4. Use the scaled drawing to determine the diameter of the wheel of the turbine and the diameter of the axle. Use the formula below to determine the mechanical advantage of the water wheel. Record the data.
Procedure for determining mechanical advantage of the grist mill:

Mechanical Advantage of the water wheel = Diameter of the wheel of the turbine ÷ Diameter of the axle

Exploration (Visit to San José Mill):

THE WALL OF THE CONTAINMENT AREA CURVES INWARD. BE CAREFUL! DO NOT STAND ON OR CLIMB OVER THE FENCE.

1. Each team takes measurements of the mill.

a. Measure the depth of the containment area using a plumb bob on a string.
b. Using the scaled drawings determine the vertical distance found in the chute. (This is an increase in the depth of the contained water.)
c. Calculate the pressure of the water. Record your data.

2. Each team finds the dimensions of and calculates the chute opening.

Area = Length X Width.

Record your data. Use your data to calculate the force of water on the turbine wheel.

3. Using the scaled drawings determine the circumference of the turbine wheel and the circumference of the axle. Formula to calculate the diameter of the wheel and axle.
C = circumference
$\pi = 3.14$
D = Diameter
$C = \pi D$
Calculate the mechanical advantage of the turbine wheel of the gristmill. Record your data.

4. Sketch the mill parts with the measurements.

5. Develop a flow chart to show how the water system of the mill worked.

Elaboration (Post-visit):

How does the depth of the water in the mill containment area affect the force of the water against the mill wheel?

1. Use PVC pipe 2 inches (5cm) in diameter and 2 meters tall. The pipe should have holes of equal size drilled along the side with vertical spacing of every 20cm between each hole. Each hole has a stopper.
2. One student holds the pipe and removes the stopper when the timer indicates.
3. Another student uses a hose to add water to the top of the PVC pipe to keep it at the same level.
4. A third student measures the number of rotations of a plastic wheel (pinwheel) per second held in each stream of water.
5. A fourth student measures the time so the pinwheel has water fall on it for the same period of time at each hole.
7. All data are recorded. Graph the height of the water column against number of rotations per second.

How does the depth of the water in the mill's water containment area affect the volume of the flow of water? Make a hypothesis about the amount of water collected in a graduated cylinder in 20 seconds.

1. Use the same PVC pipe used in the above procedure.

2. One student the amount of water that is coming from the pipe in a given period of time.

3. After all of stoppers are in place, one student fills the PVC pipe with water. As a stopper is removed, this student maintains the water level in the pipe.

4. Pull the bottom stopper and catch all the water that comes from the bottom opening in 20 seconds.

5. Measure the water in a graduated cylinder and record the data.

6. Repeat these procedures by plugging the bottom hole and pulling the plug from the hole 20 cm above. Keep repeating until all holes are tested.

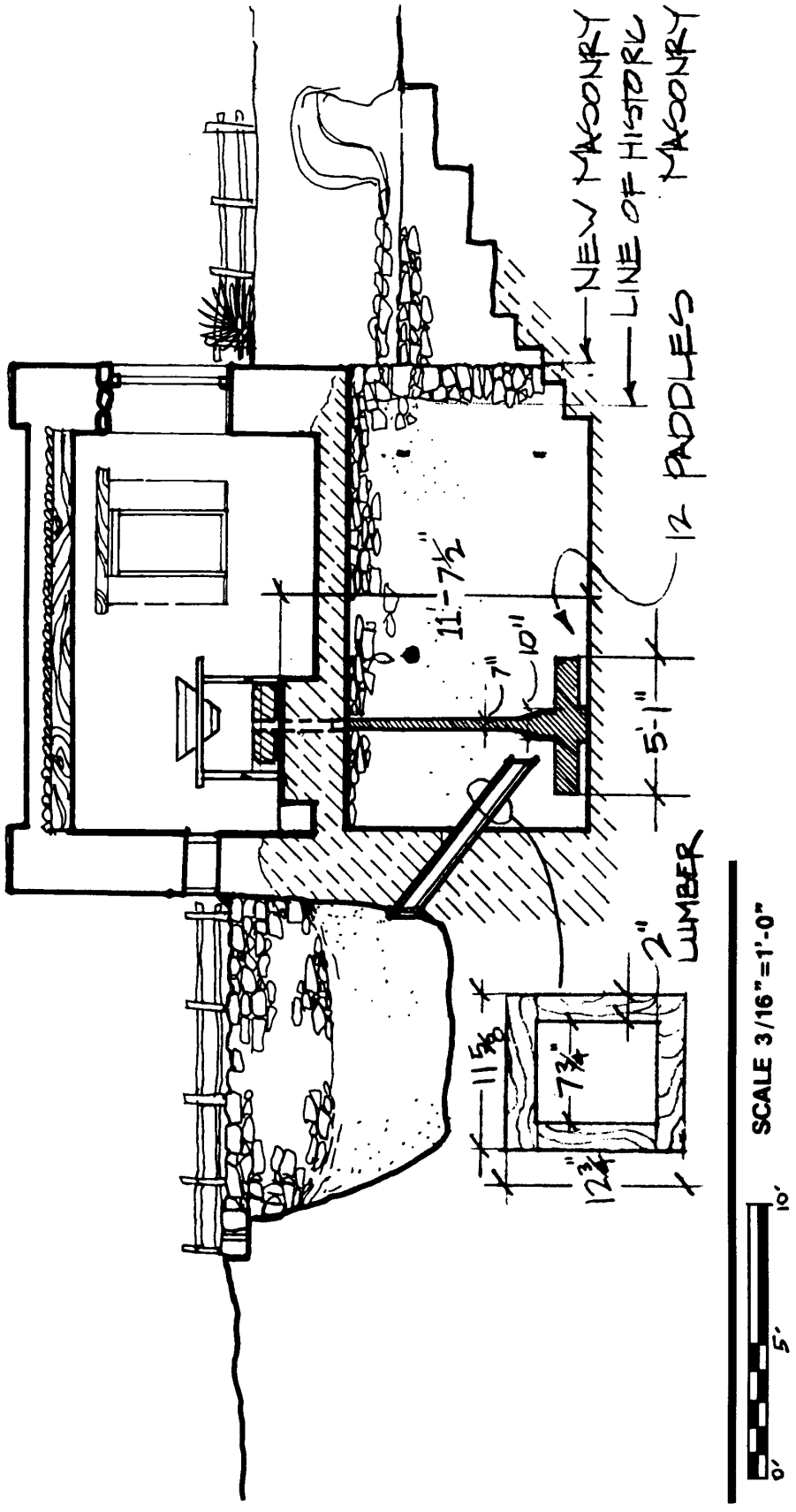
7. Make a data table and then graph the data. Plot water depth against the volume of water collected.

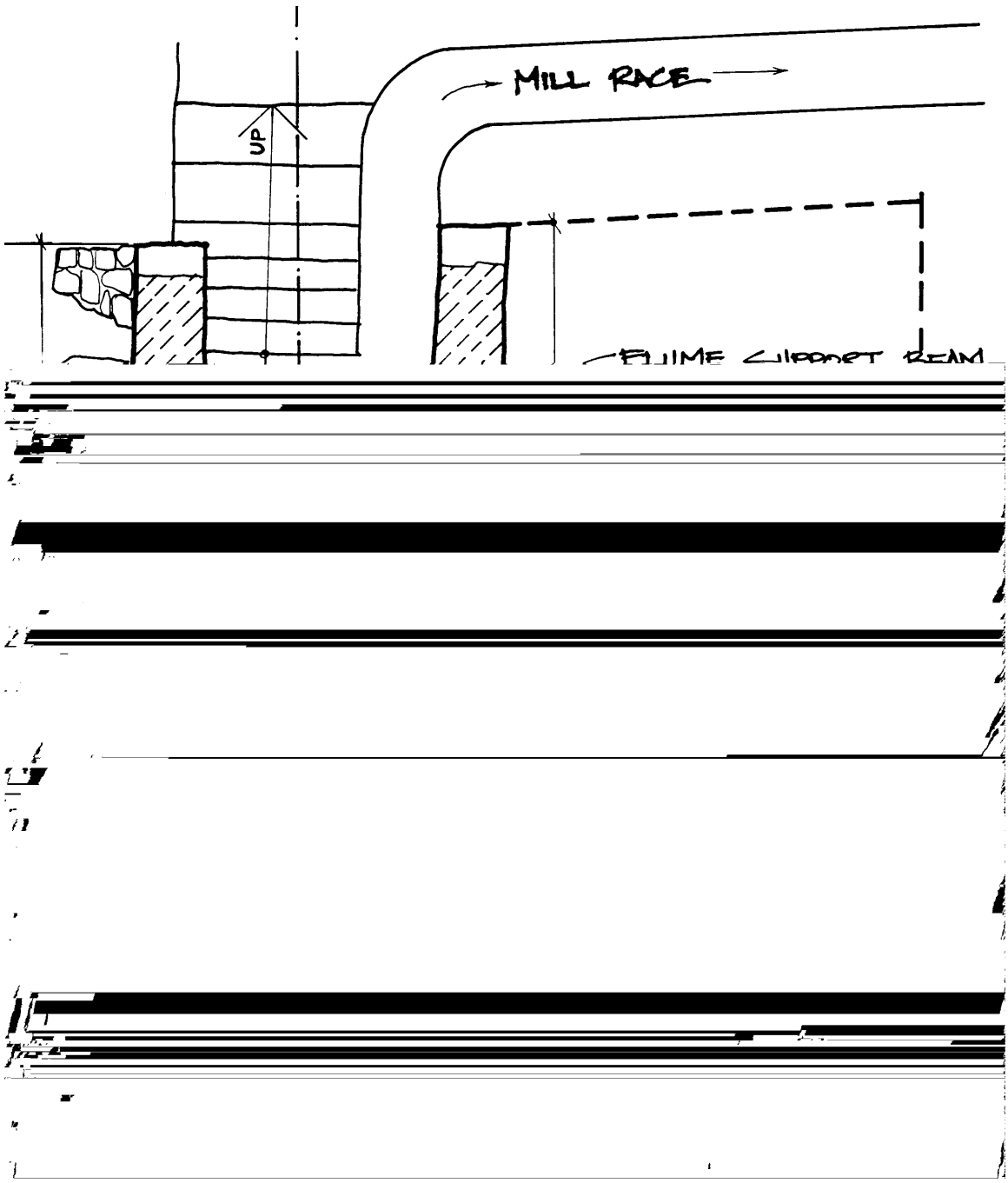
8. Does your data support your hypothesis?

Does the diameter of the well affect water pressure? Make a hypothesis about the effects of the well's diameter on water pressure.

1. Repeat the above experiment, but with a 4-inch PVC pipe. Maintain the same-size hole and the same depth of water as with the 2-inch PVC pipe. Only the hole at the bottom needs to be used because

SAN JOSÉ MILL

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